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A First View of Polar Vortex Evolution and Breakup From the Microwave Limb Sounder on Aura

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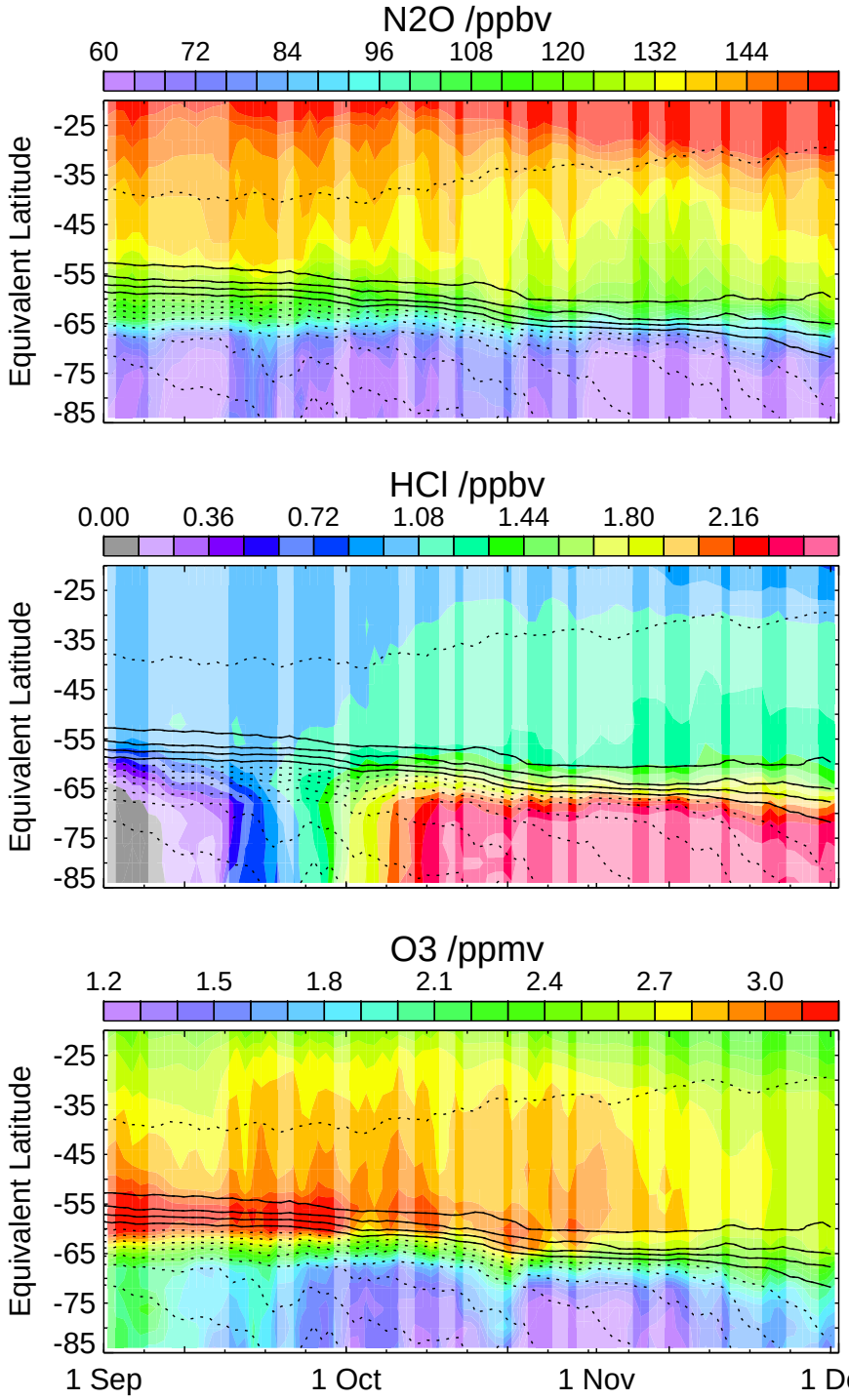
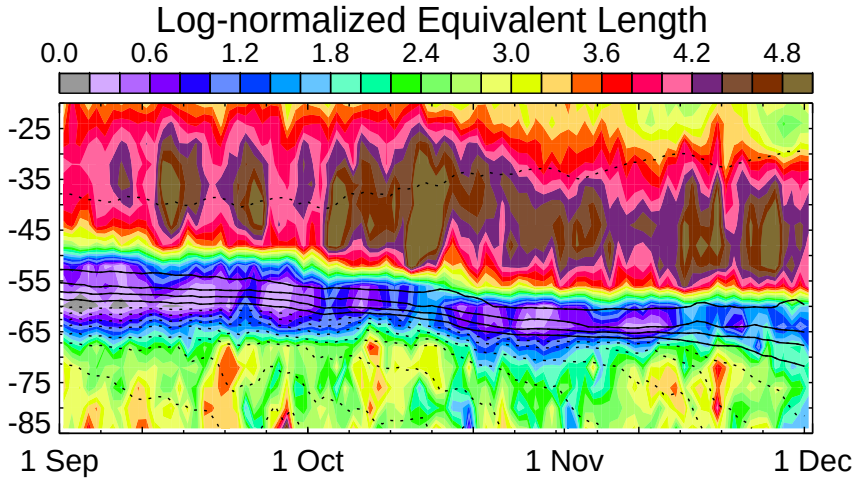
Introduction

- Aura MLS measures several species that are useful as tracers of transport
- We examine MLS observations of N_2O, H_2O, O_3, HCl and CO to illustrate the evolution and breakup of the Antarctic vortex in 2004
- Initial retrievals are used here; new software now being implemented offers substantial improvements
- Aspects of H_2O, O_3, HCl and CO data are discussed in talks/posters by Read et al., Froidevaux et al., and Filipiak et al.
- Initial N_2O data show some biases, but exhibit expected morphology
- We follow up the previous [*Santee et al*] talk by examining the fate of chemically processed air as the vortex decays

- Potential Vorticity (PV) from NASA's Global Modeling and Assimilation Office's GEOS-4 dataset is used to demark the polar vortex, and as a vortex-centered coordinate (when expressed as equivalent latitude, EqL)
- Effective diffusivity (K_{eff}; expressed as the dimensionless quantity log-normalized equivalent length) calculated from the GEOS-4 PV is used to identify mixing regions and transport barriers [e.g., *Haynes & Shuckburgh*, 2000, JGR; *Allen & Nakamura*, 2001, JGR]

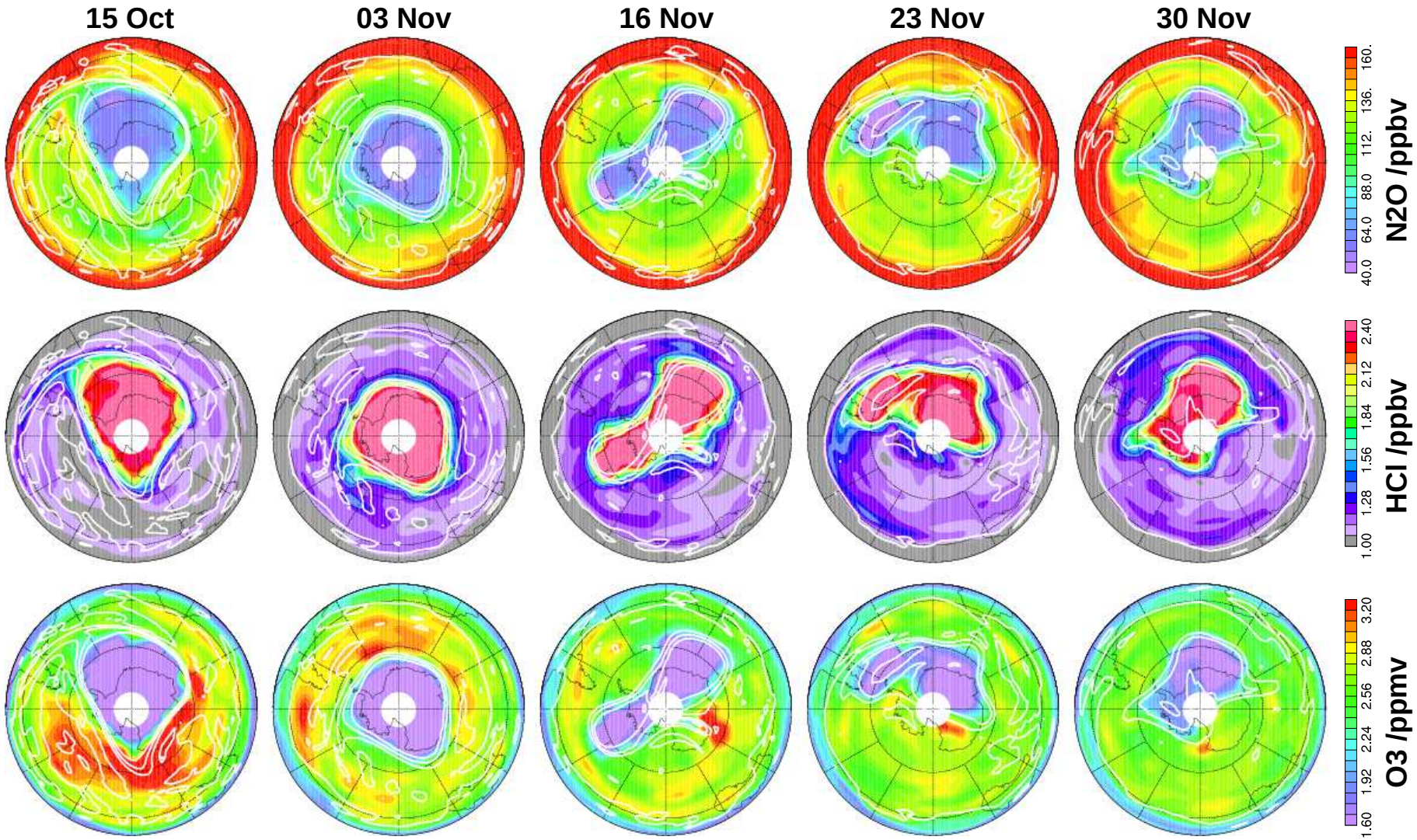
Tracer Time Evolution in the Lower Stratosphere (520 K, ~19 km)





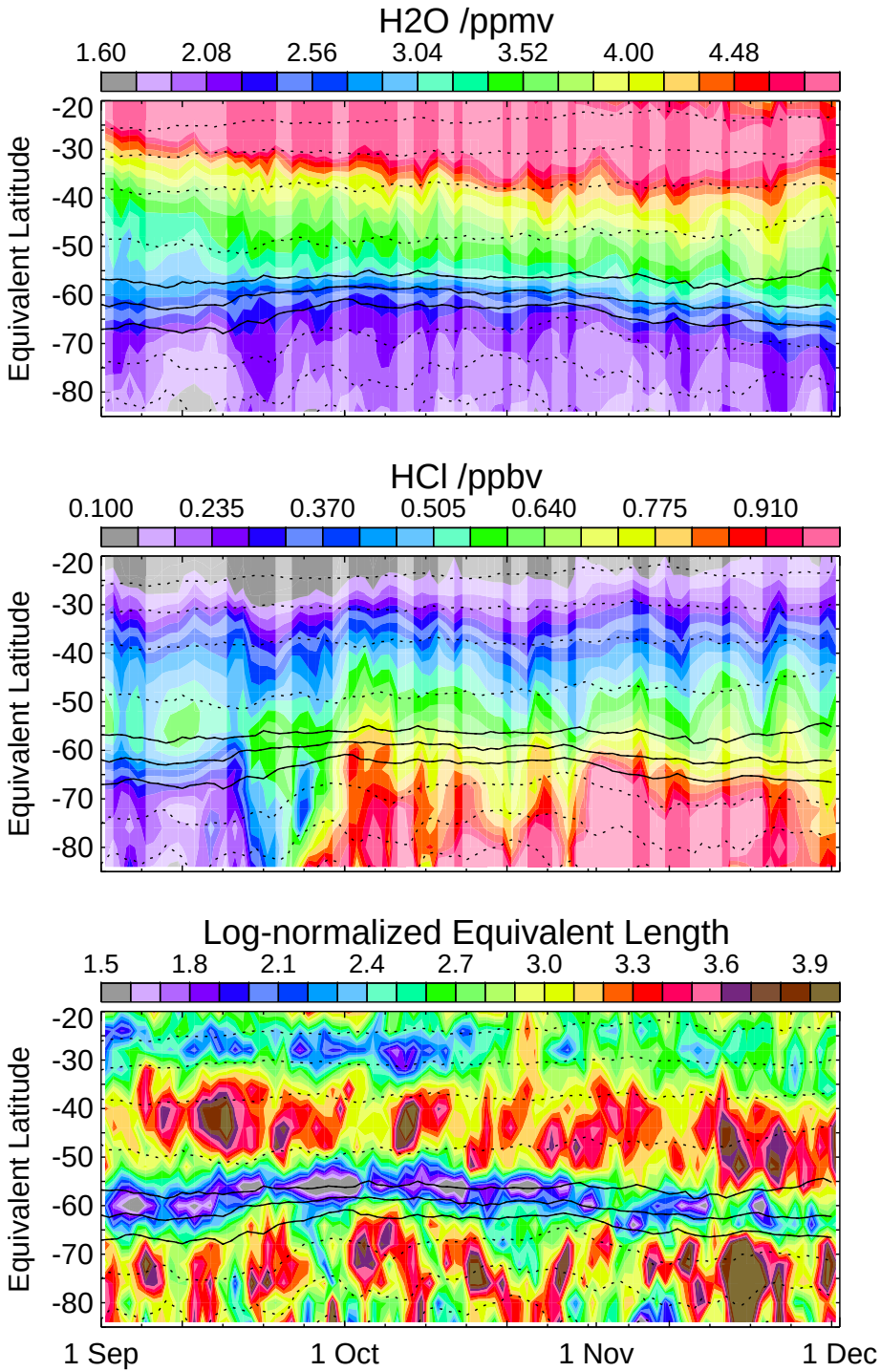
- Data are filled using Kalman smoother, as in *Santee et al* [previous talk]; pale colors show periods with sparse or missing data
- Low K_{eff} values show polar vortex transport barrier, high values mixing regions
- Vortex shrinks starting in mid-October
- Transport barrier does not weaken much until mid-November – confined vortex material persists through early December

Daily Snapshots in the Lower Stratosphere (520 K, ~19 km)

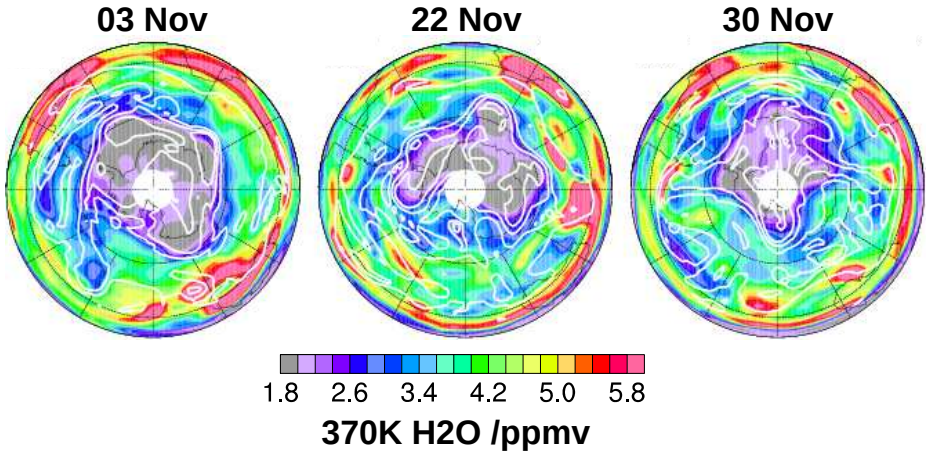


- N_2O, HCl and O_3 maps show:
  - Filamentation and vortex-edge erosion (e.g., 15 Oct, 23 Nov)
  - Intrusions into vortex (e.g., 23 Nov)
  - Increased mixing of vortex-edge air into midlatitudes
  - Persistence of well-confined region of vortex air

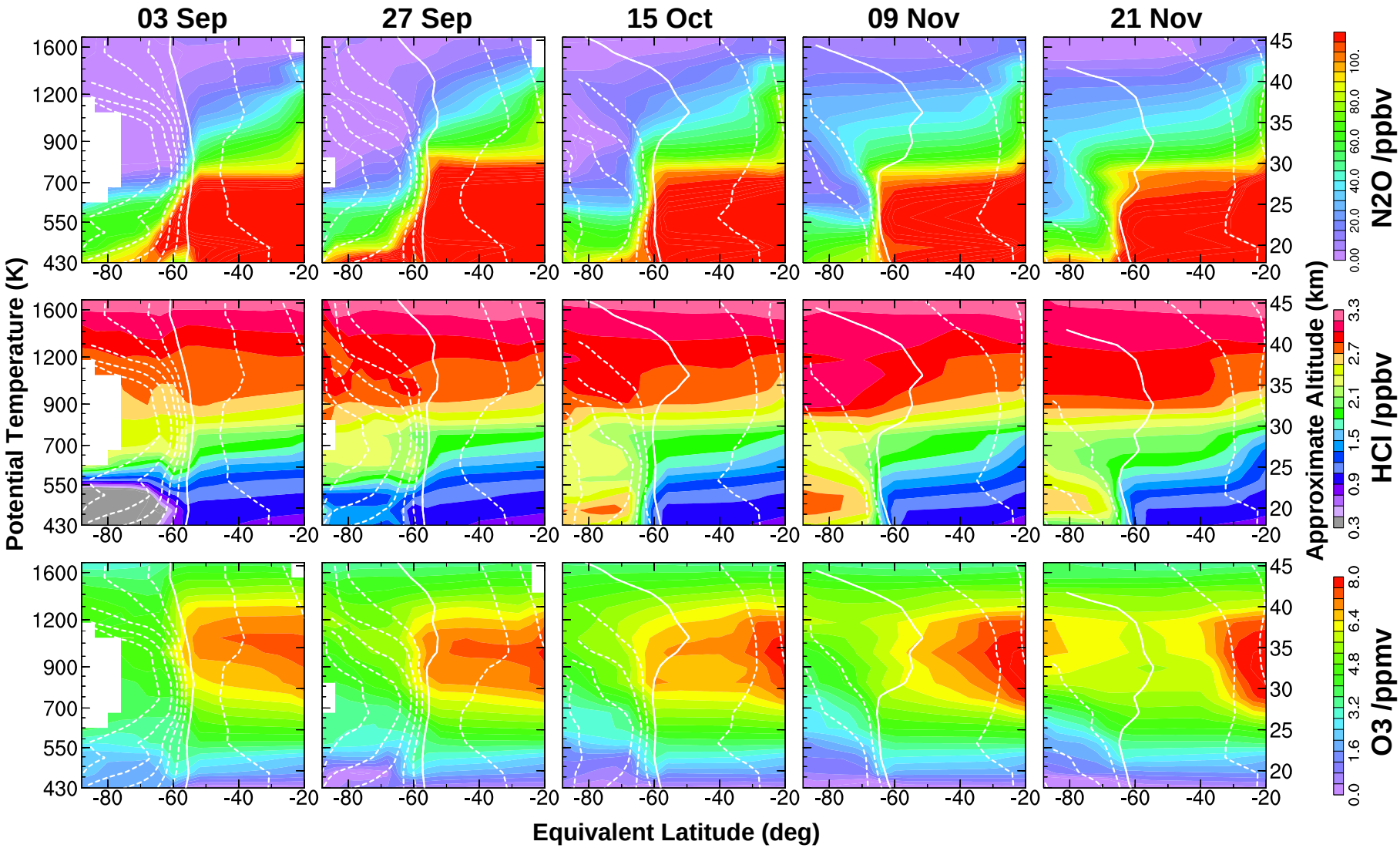
The Subvortex and Lowermost Stratosphere (370 K, ~12 km)



- 370 K is in the troposphere in the tropics, in the stratosphere at higher latitudes
- The subvortex refers to the lowest reaches of the stratospheric polar vortex, where there is less complete confinement than at higher levels
- Future retrievals in UTLS region will be much improved – but subvortex (and tropopause) transport barriers are clearly defined and coincide with minima in K_{eff}
- H_2O (and O_3, HCl, not shown) maps show synoptic evolution consistent with GEOS-4 PV fields

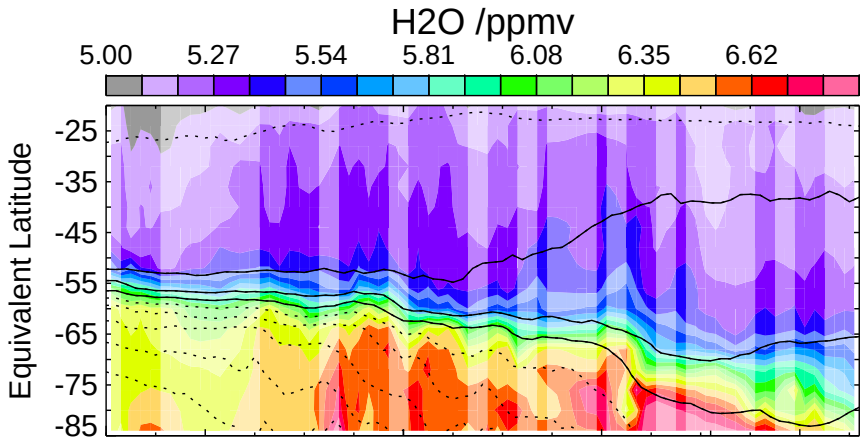


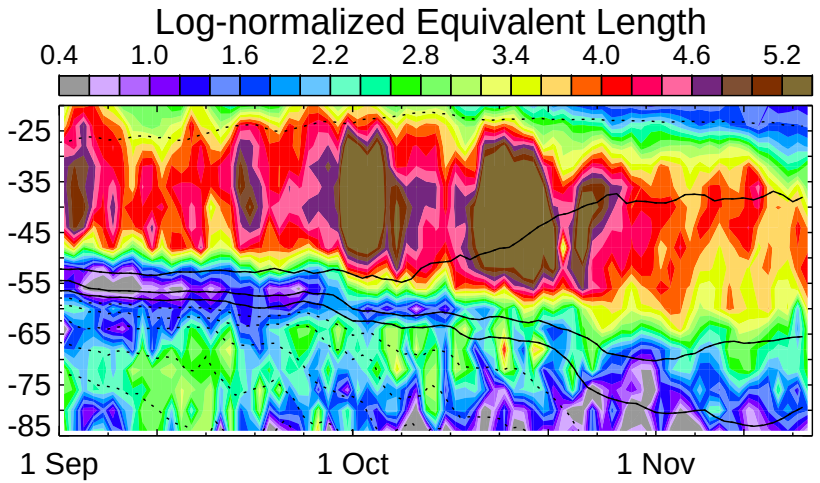
Overview of Three-Dimensional Vortex Evolution

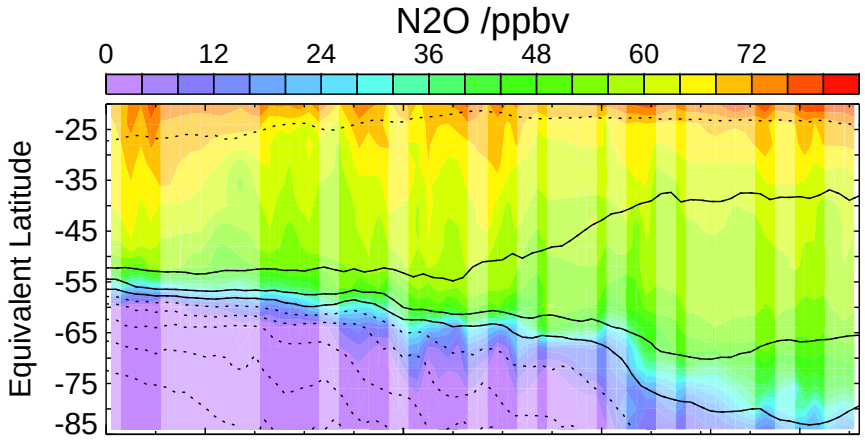


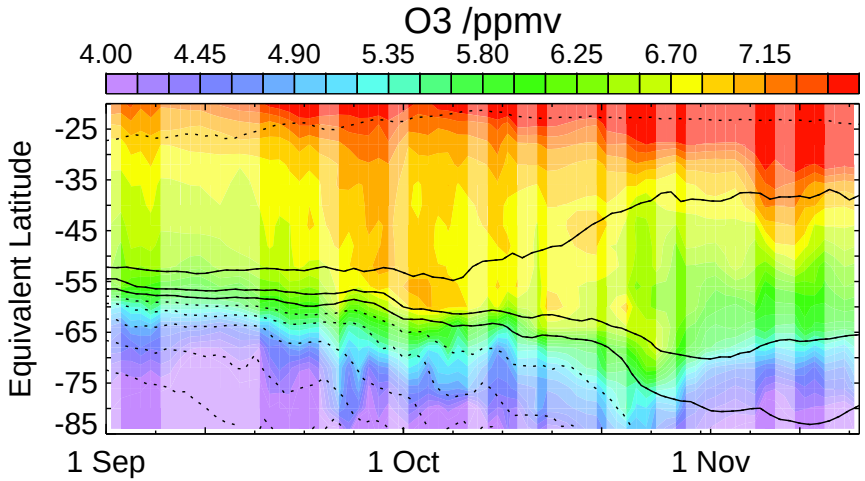
- As vortex decays from top down, extra-vortex air is transported to high equivalent latitudes at progressively lower levels
- N_2O fields clearly show continuing descent through mid-Nov
- Lower stratospheric vortex ozone increases after mid-Oct from continued descent and mixing with extravortex air

Tracer Time Evolution in the Middle Stratosphere (850 K, ~30 km)



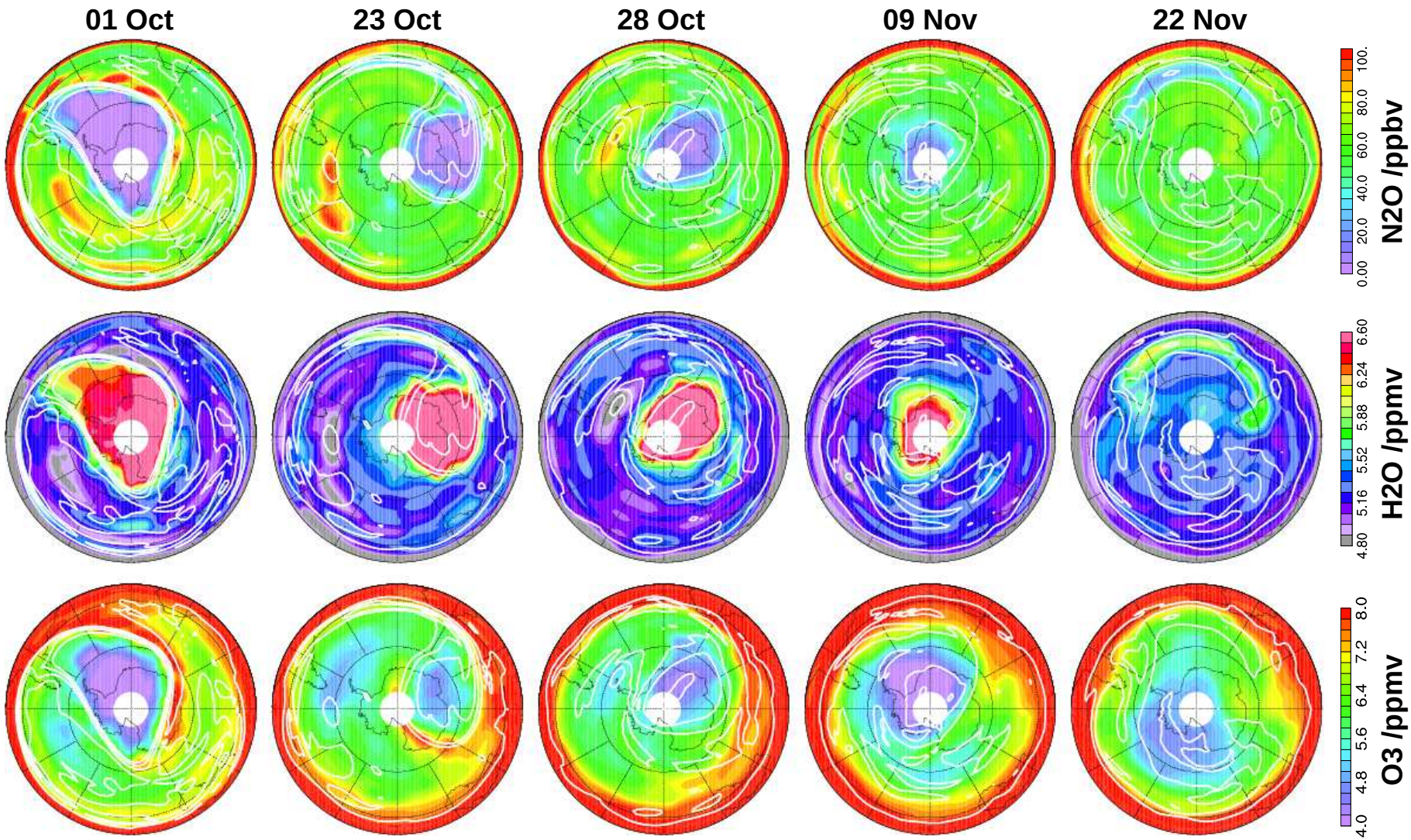






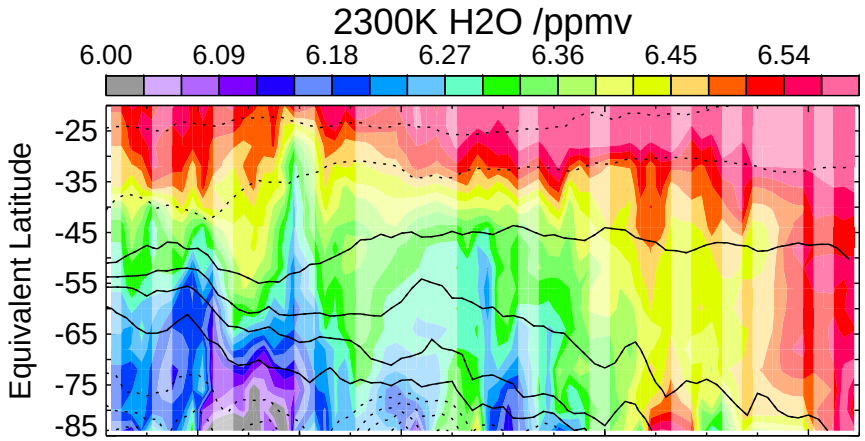
- Midstratospheric vortex breaks up by late October
- Weakened transport barrier, and enhanced midlatitude mixing by end of September
- Ozone shows transport of low-latitude air, “low-ozone pocket” formation (see next slide)
- Decreased high-EqL ozone after vortex breakup due to summer photochemistry

Daily Snapshots in the Middle Stratosphere (850 K, ~30 km)

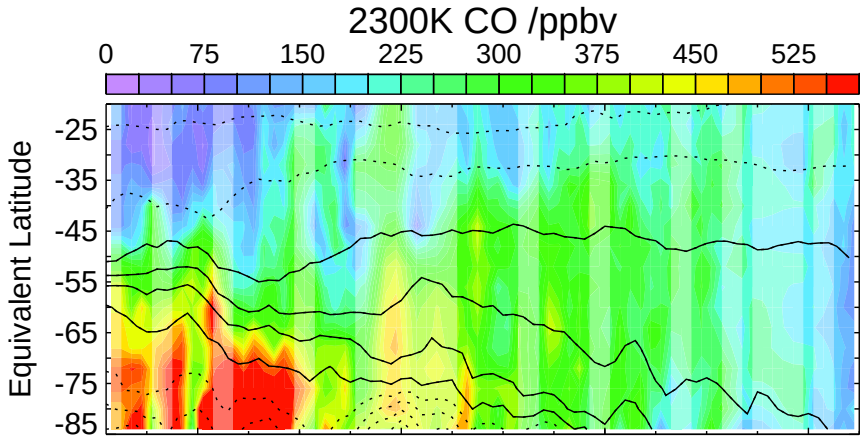


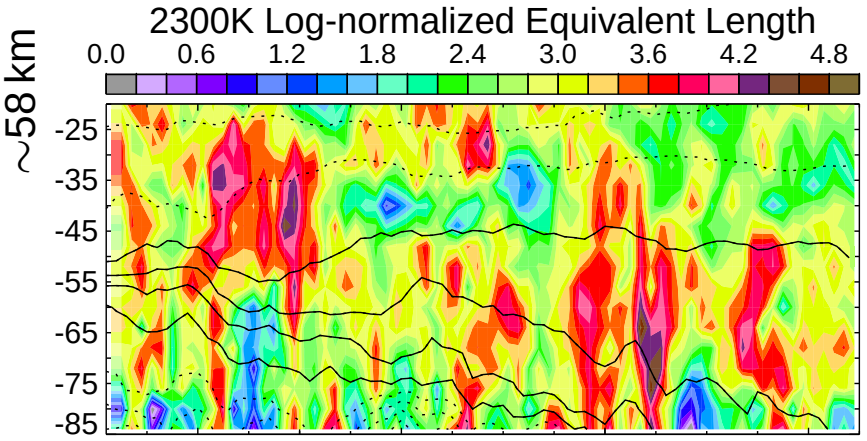
- H_2O and N_2O show low-latitude air drawn up and entrained into anticyclone
- Low-ozone pockets form photochemically in air confined in anticyclone
- Remnant of vortex air apparent on 22 Nov in N_2O and H_2O

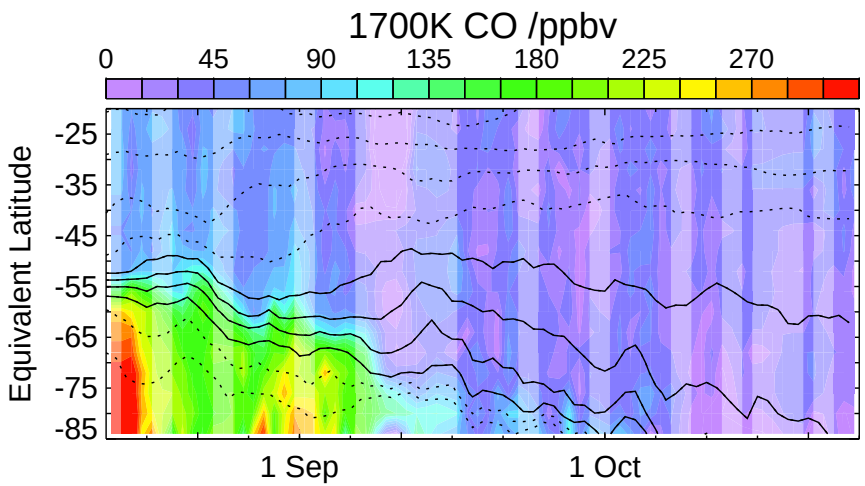
The Upper Stratosphere (1700 K) and Lower Mesosphere (2300 K)

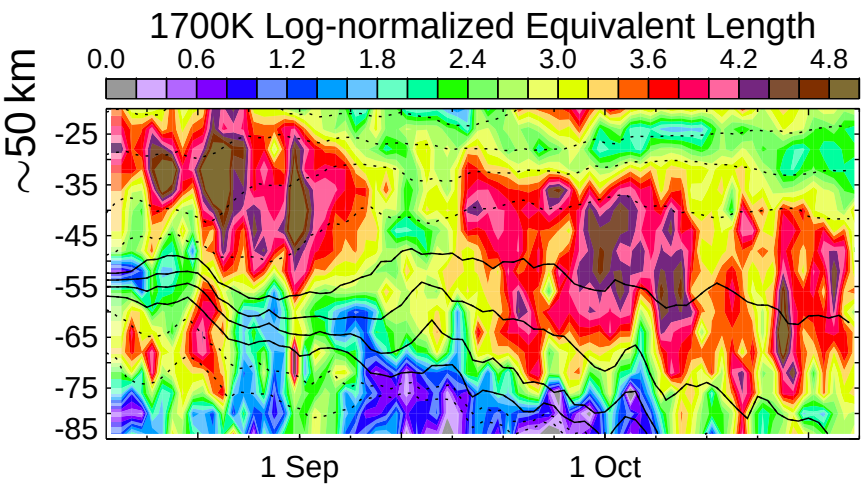


- The transport barrier is less distinct in the lower mesosphere
- Upper stratospheric vortex dissipates by beginning of October

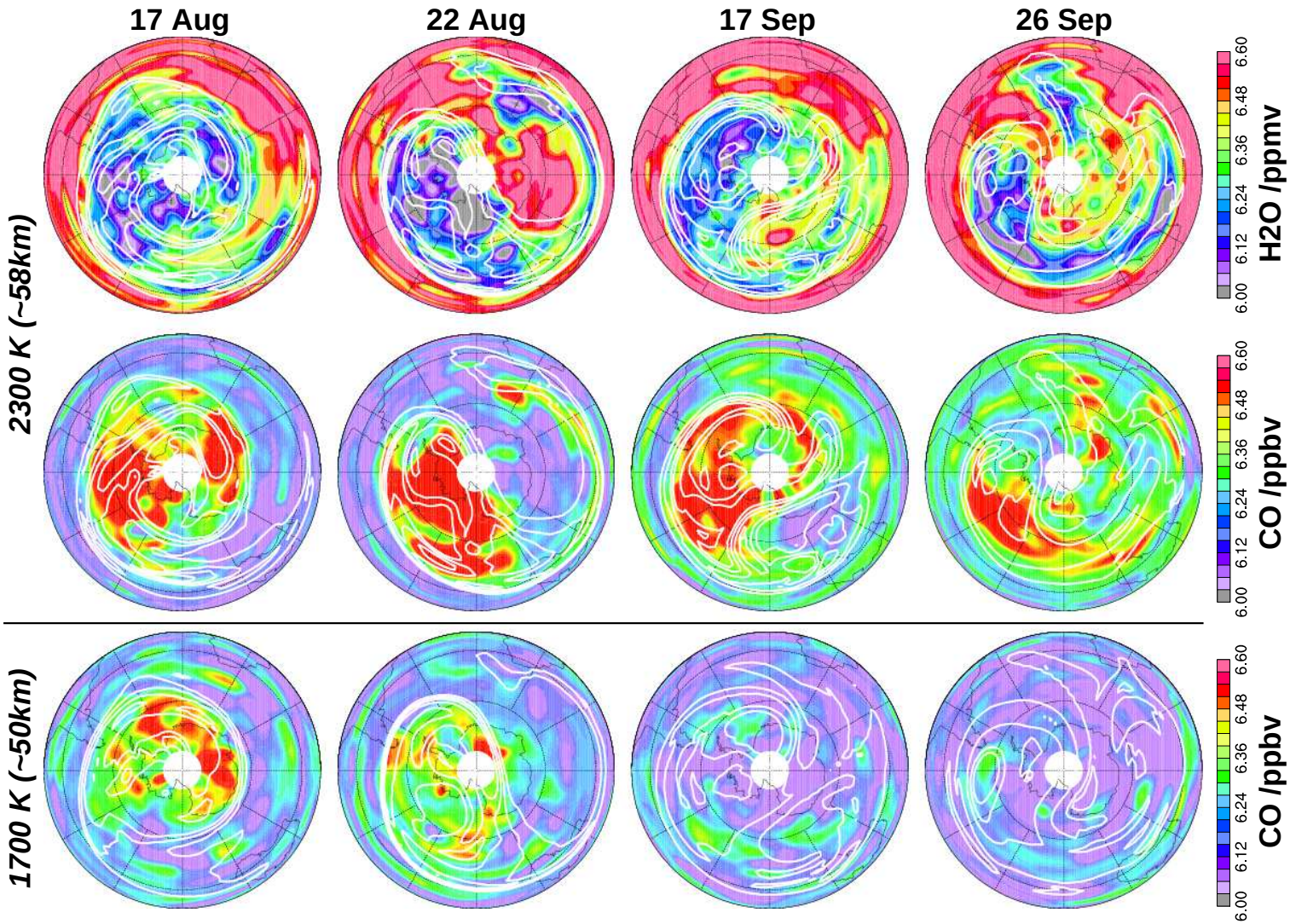








Daily Snapshots in the Upper Stratosphere/Lower Mesosphere



- CO “noisy” product for MLS – but can still distinctly see confinement in vortex in upper stratosphere/lower mesosphere
- At 2300 K, both CO and H_2O correspond well with GEOS-4 PV
- 1700 K H_2O gradients are too weak to show transport features

Summary:

- Aura MLS trace gas and GEOS-4 meteorological data give a consistent picture of the evolution and breakup of the 2004 Antarctic vortex in the lowermost stratosphere through the lower mesosphere:
  - Lower stratospheric vortex in process of decaying, with region of well-confined, ozone-depleted air still apparent by 5 December
  - MLS observations show good correspondence with dynamical evolution in subvortex region, where chemically processed air is less well-confined and mixes more into lower latitudes
  - Descent in the vortex in the lower stratosphere continues through mid-November, consistent with previous studies [e.g., *Manney et al*, 1994, JAS]
  - The mid-stratospheric vortex broke up by late October, following an early October breakup in the upper stratosphere
- Even in these preliminary retrievals, the Aura MLS dataset provides a wealth of information on transport processes and vortex evolution
  - Compared to UARS MLS, addition of N_2O, HCl and CO measurements, and extended coverage for and improvements in O_3 and H_2O, enhances our ability to track transport processes using Aura MLS data
  - Aura MLS observations will be particularly valuable for improving our understanding of stratospheric vortex-related transport in the regions around the tropopause and stratopause